Nonlinear shear wave propagation in a fragile granular medium

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ABSTRACT

Force transmission and elastic wave propagation in both dry and water-saturated granular materials strongly depend on the solid frame of the particles assembly. The jammed state emerges when the density of randomly packed particles is high enough so that the particles all interact with their neighbors and resist flow. However the resulting inhomogeneous contact force network is metastable. Under external driving such as shearing or shaking, a transition from a jammed solid state to an unjammed liquid state may occur above a certain threshold. The associated intermittent response and collective behaviour, e.g., avalanche or shear band formation, may be conveniently described by the jamming phase diagram [1].

Sounds waves provide controlled oscillatory measurements that may be compared with simulations. Indeed, the long-wavelength coherent waves give access to the elastic modulus whereas the short-wavelength scattered waves are sensitive to any rearrangement of the contact force network [2]. Coherent wave velocity measurements in the linear regime clearly illustrate the elastic weakening of jammed media when the confining pressure decreases [3, 4] or when the shear loading is increased prior to failure or flow [5].

In this talk, we investigate the shear elastic wave propagation along the free surface of glass bead packings immersed in water using ultrasound speckle interferometry [6]. Unlike usual measurements of effective viscosity in glassy transition [1], we monitor the nonlinear softening of the shear wave velocity from a jammed state to an unjammed state as the shear driving is increased.

Particularly, we find that unjamming takes place between two stages: one involves irreversible sound-induced softening but without detectable motion of grains, the other one happens at highest driving and is accompanied with a plastic granular flow via dilatancy. The plastically fluidized zone is localized close to the driving source where the shear modulus softening is up to 85%. Here the shear waves act not only as a probe but also as a pump that fluidizes the jammed solids [7].

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